# ADVERTISEMENT.

*By* Joseph Watts, *at the* Half-Moon *in* St. Paul's *Church-yard*,

ALL Gentlemen and Others, may have most sorts of Acts of Parliament, Proclamations, Declarations, Orders of Kin and Council, Speeches of King, Lord Chancellor, and Speaker in Parliament, *&c.* Pamphlets of all sorts, *viz.* Pamphlets relating to the State, Sermons, Controversies about Church-Government, Tracts of Divinity, and other Miscellaneous Tracts, *&c.* Also Tryals, Narratives and Gazetts, *&c.*

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# IMPRIMATUR,

*Rob. Midgley, October* the 9*th*, 1685.

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# IMPRIMATUR,

*Rob. Midgley, October* the 9*th*, 1685.

OF THE

# UNEQUALITY

OF

# NATURAL TIME,

WITH ITS

*REASON* and *CAUSES.*

TOGETHER WITH

# A TABLE

OF THE

TRUE ÆQUATION

OF

*NATURAL DAYES.*

Drawn up Chiefly for the Use of The GENTRY, in Order to their more true Adjusting, and right Managing of

*Pendulum Clocks*, and *Watches.*

By *John Smith*, C. M.

*LONDON*,
Printed for *Joseph Watts*, at the *Half-Moon* in St. *Paul's* Church-yard. 1686.

# A TABLE of Equations,

## FOR REDUCING The Unequality of NATURAL DAYS TO A MEAN and EQUAL TIME.

Designed chiefly in order to the more true Adjusting, and right Managing of *Pendulum* CLOCKS and WATCHES.

By *JOHN SMITH*, C. M.

| Day. | Janua. Sec. | Febru. Sec. | March Sec. | April Sec. | May. Sec. | June. Sec. | July. Sec. | Aug. Sec. | Sept. Sec. | Octob. Sec. | Nov. Sec. | Dec. Sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 | ⊙ 0 | 17 | 17 | 3 | 1 | 7 | 9 | 20 | 14 | 9 | 29 |
| 2 | 23 | 2 | 17 | 16 | 3 | 1 | 7 | 9 | 20 | 14 | 10 | 30 |
| 3 | 22 | 2 | 18 | 16 | 1 | 12 | 7 | 9 | 21 | 13 | 10 | 30 |
| 4 | 21 | 4 | 18 | 15 | 0 | 12 | 6 | 11 | 21 | 13 | 10 | 30 |
| 5 | 20 | 4 | 18 | 15 | 0 ⊙ | 12 | 6 | 12 | 21 | 13 | 11 | 30 |
| 6 | 19 | 4 | 18 | 14 | 1 | 13 | 6 | 13 | 21 | 13 | 12 | 30 |
| 7 | 18 | 5 | 18 | 14 | 2 | 13 | 6 | 13 | 22 | 12 | 12 | 30 |
| 8 | 17 | 5 | 18 | 14 | 2 | 13 | 5 | 14 | 22 | 11 | 13 | 30 |
| 9 | 16 | 6 | 18 | 14 | 3 | 13 | 4 | 14 | 22 | 10 | 15 | 30 |
| 10 | 16 | 8 | 18 | 13 | 3 | 13 | 4 | 15 | 21 | 9 | 17 | 30 |
| 11 | 16 | 8 | 18 | 13 | 3 | 13 | 3 | 15 | 21 | 8 | 17 | 30 |
| 12 | 16 | 9 | 18 | 12 | 4 | 13 | 2 | 15 | 20 | 7 | 18 | 30 |
| 13 | 16 | 9 | 19 | 12 | 4 | 13 | 2 | 16 | 20 | 7 | 18 | 30 |
| 14 | 15 | 10 | 19 | 11 | 5 | 13 | 1 | 16 | 20 | 6 | 19 | 31 |
| 15 | 15 | 10 | 20 | 11 | 5 | 13 | 0 | 17 | 20 | 6 | 20 | 31 |
| 16 | 14 | 11 | 20 | 10 | 6 | 12 | 0 ⊙ | 17 | 20 | 5 | 21 | 31 |
| 17 | 13 | 12 | 20 | 10 | 6 | 12 | 1 | 17 | 20 | 4 | 22 | 31 |
| 18 | 12 | 13 | 20 | 10 | 6 | 11 | 2 | 18 | 20 | 3 | 23 | 30 |
| 19 | 11 | 13 | 20 | 10 | 6 | 11 | 3 | 18 | 19 | 3 | 23 | 30 |
| 20 | 11 | 13 | 19 | 10 | 7 | 11 | 4 | 19 | 19 | 2 | 24 | 30 |
| 21 | 10 | 14 | 19 | 9 | 8 | 11 | 4 | 19 | 19 | 1 | 24 | 30 |
| 22 | 9 | 14 | 19 | 7 | 8 | 11 | 4 | 19 | 19 | 0 | 24 | 30 |
| 23 | 8 | 15 | 19 | 7 | 9 | 10 | 4 | 19 | 19 | 0 | 25 | 30 |
| 24 | 6 | 15 | 19 | 7 | 10 | 10 | 5 | 19 | 18 | 1 | 25 | 29 |
| 25 | 5 | 15 | 19 | 6 | 10 | 10 | 5 | 20 | 17 | 2 | 25 | 28 |
| 26 | 4 | 15 | 19 | 5 | 11 | 10 | 5 | 20 | 17 | 2 | 25 | 28 |
| 27 | 3 | 16 | 19 | 5 | 11 | 10 | 5 | 20 | 16 | 3 | 26 | 28 |
| 28 | 3 | 17 | 19 | 5 | 11 | 9 | 6 | 20 | 16 | 4 | 26 | 27 |
| 29 | 2 | | 19 | 4 | 11 | 9 | 7 | 20 | 15 | 6 | 27 | 27 |
| 30 | 1 | | 18 | 4 | 11 | 8 | 8 | 20 | 15 | 7 | 27 | 25 |
| 31 | ⊙ 0 | | 17 | | 11 | | 9 | 20 | | 8 | | 24 |
| | Clocks gain this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks gain this Month Min. Sec. | Clocks gain this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks lose this Month Min. Sec. | Clocks gain this Month Min. Sec. | Clocks gain this Month Min. Sec. |
| Sum | 6 26 | 4 29 | 9 37 | 5 16 | 2 47 | 5 43 | 0 6 | 8 23 | 9 41 | 2 20 | 9 38 | 15 9 |

This Table contains those Seconds of Time that each natural Day is either longer or shorter than the mean or equal day, or such a one as contains in length the just time of 24 hours; from which Mean Day the Natural ones differing almost continually in length, this Table shall still give you the difference between them, and (by inspection only) inform you what quantity of time each natural day is either more than 24 hours long, or less.

*Note*, That upon each particular day, a Clock that is well adjusted to a mean or 24 hour day, shall then either gain or lose just so much time, as that natural day is either longer or shorter than the mean day:

Therefore, if a Clock, having been first set right to the Sun the first day of any particular Month, shall either gain or lose in that whole Month so much in time as the whole sum of Equations for that Month amounts to, (which you shall find noted down at the bottom of every particular Column) then is it well adjusted to the mean, Equal or 24 hour Day; but if it have not either got or lost so much as the whole sum of Equations for the whole time it has gone in do's amount to, then must its motion be regulated as occasion requires, by skrewing up the Bob to make it go faster, in case it has not got enough; or else letting the Bob down lower, to make it go slower, in case it hath not lost so much as the whole sum of Equations do amount to for the time it has gone in.

*For the more particular Explanation and Use of this* Table, *consult the Book it self, sold by* J. Watts *at the* Half-Moon *in St.* Paul's Church-yard, 1686.

# OF THE UNEQUALITY OF NATURAL TIME, &c.

THE Vibrations of a long and weighty *Pendulum*, although it be juſtly eſteemed to be the moſt exact and ſteady of all Natural Motion; yet is it not capable of regulating the *Index* of a Clock to ſuch a pitch of Perfection, as continually to point out the ſame time that ſhall be given by the Sun on the Lines of an exact and true Dial.

The truth of which is ſufficient-

ly made evident by the moſt exact and critical Experiments: For, let all the moving parts, of a *Pendulum* Clock, be contriv'd with the greateſt Skill and Judgment, and then made up by the moſt cunning and curious Hand, and after all this be adjuſted by the utmoſt Care and Diligence of Man; yet ſhall not the Motion of it correſpond ſo continually with the Hours given by the Sun, but that in ſome conſiderable quantity of Time you ſhall be ſenſible of gain or loſs in the Motion of it.

The true Reaſon of which Variation proceeds not from any Defect that may be attributed to the Motion of the *Pendulum*, (of whoſe exactneſs we are by many curious Experiments ſufficiently ſenſible;) but rather from an Unequality legible

gible and eaſie enough to be diſcover'd in the diurnal Motions of the Sun.

Vulgarly, for the moſt part, the Sun is indeed accounted to be the Standard and Meaſure of all equal Time, and Men generally eſteem Natural Dayes to be all of one length, as containing the juſt time of 24 Hours; but upon a more exact and curious Scrutiny, theſe vulgar Suppoſitions are found to be falſe: For, neither is the Sun's Motion found to be exact, being in appearance to us, ſometimes ſwift, and at other times more ſlow; nor are the Dayes themſelves, accounted from Noon to Noon, of equal lengths, ſome Dayes containing more Time than ſome, and others leſs; there being a natural neceſſity, that the unequal Motions of the

Sun ſhould produce ſuch inequalities in the lengths of thoſe natural Days that are bounded by it.

For a natural Day being compoſed of that ſpace of Time, in which any one Place or Point of the Earth is moved in its diurnal Motion Eaſt-ward, from the Meridian Sun of any one Day, to that of the next; it will follow, that theſe Dayes can never be equal, unleſs the Sun in that ſpace of Time be ſo mov'd in her annual Orb, as to cut out equal Diviſions on the *Æquinoctial* upon the Meridian of every Day; which Diviſions ſo interſected, are by the Learned termed, the *Right Aſcenſions*: For whenever the Right Aſcenſion either of Sun or Star is mentioned, we are to underſtand by it, thoſe Degrees of the *Æquinoctial* that are interſected

ed by that Meridian, on which either Sun or Star have then their place.

But that the Sun between each Meridian does not move ſuch juſt and certain Spaces in her own Orb, as thus to interſect equal Diviſions on the *Æqui-nox*, upon every Meridian, needs no other evidence than what either Calculation it ſelf affords, or Globes by an occular Inſpection demonſtrate to us. By Calculation, if an exact Table of *Right Aſcenſions* be compoſed, for the Meridian, or Noon-time of each particular Day, there will be found almoſt a continual difference in the length of thoſe Interſections that are made by the Sun on the *Æqui-nox*, upon every Meridian; ſo that there will by this means be found nothing but an almoſt continual unequalneſs

qualneſs in the *Right Aſcenſions*: Which will be the more apparent, if you make an Eſtimation of the *Right Aſcenſions* of about 10 Dayes together, and compare that with thoſe of the ſame Number. The like will appear plainly, if tryed on the Globe; for if you mark out on the *Ecliptick* any 10, or more Day's Motion of the Sun, according to his true place found out in an exact *Ephimeris*, and paſſing theſe 10, or more Days motion under the Meridian, noting what Degrees on the *Æquinoctial* are then traced out, which compared with the Degrees traced out, by making the ſame number of Day's Motion in ſome other part of the *Ecliptick*, to paſs the Meridian, and the difference of *Right Aſcenſions* included between thoſe two equal number of Dayes will plainly appear.

All

All which Irregularities, or difference in *Right Aſcenſion*, proceed from two principal Cauſes: 1. From the different Poſitions: And, 2. From the *different Centres* of thoſe *Orbs* in which, and according to which the Sun and Earth do move; from whence ariſes a natural neceſſity, that between two ſuch regular and equal Motions, whoſe Poſition is thus oblique, thoſe appearing differences ſhould ſtill ariſe; for though both Sun and Earth, the one in his annual the other in it's diurnal Revolutions, be rationally ſuppoſed to be regular and equal in their own Motions; yet in regard of the different Poſitions of their Spheres, the *Right Aſcenſions* that are made by them cannot be equal; it being impoſſible that the Sun, when near *Aries* and *Libra*, where he moves croſs

croſs the Equinoctial, ſhould then in any particular number of days make ſo great an alteration in *Right Aſcenſion*, as he muſt do near the two Tropicks, where both Equinoctial and Ecliptick run paralel one to the other; and accordingly by the beſt Tables of *Right Aſcenſion*, 'tis found that the *Right Aſcenſions* of 10 daies motion of the Sun near the Tropick of *Capricorn*, ſhall ariſe to above 11 degrees 30 minutes, whereas that of the ſame number of daies near the Equinoctial Point of *Aries* ſhall ſcarcely amount to 9 degrees.

Moreover, from the eccentricity of theſe Orbs, another irregularity does happen in the *Right Aſcenſions*, for the Centre of the Earth, upon which it turns round in it's daily Revolutions, being not the

the ſame with the Centre of the Suns Orb, it follows that the apparent Equinoxes pointed out by an imaginary line drawn through the centre of the Earth, and interſecting the Ecliptick, ſhall divide that Circle into two unequal parts; from whence it ariſes, that the Sun muſt ſpend more daies in paſſing through one half of the Ecliptick, than he does in paſſing through the other; and accordingly by experience he is found to move through that part between *Libra* and *Aries* in 179 daies, but in paſſing between *Aries* and *Libra* he takes up 186, which is 7 dayes more; ſo that in that part of the Year between *September* and *March*, he ſeems to us to be ſwift in motion, but in the other part between *March* and *September* his apparent courſe is more ſlow; which

which seeming swiftness and slowness of the Suns motion, is the cause that the *Right Ascensions* near both the Tropicks are not alike, but differ much, as do also those that are nigh the Equinoxes: for the *Right Ascension* of 10 daies motion near the Winter Tropick, is more by 60 Minutes, than that of the same number of daies near that of the Summer one; so also the *Right Ascension* of 10 daies time near *Libra*, amounts to above 30 Minutes more than those of the same number of daies near *Aries* does.

Having thus plainly demonstrated that natural daies must needs be unequal, and laid down the Causes from whence those unequalities do still arise; I suppose it may now be concluded to be extreamly unreasonable, for those that are so Nice

and

and Curious as ſome are, to expect an exact correſpondence between the times given by the motions of a Clock, and thoſe diviſions of it that are made by theſe unſteady motions of the Sun on the Lines of a Dial; for if from the Reaſons before laid down, there be in nature a neceſſity for thoſe differences of *Right Aſcenſion* before aſſerted, and that the daies which they bound, muſt differ alſo in length, correſpondent to what thoſe differences in *Right Aſcenſion* do amount to; how then is it poſſible that thoſe exact and regular motions of a *Pendulum*, to what pitch ſoever it be ſet, ſhould agree with theſe motions of the Sun, and truely divide thoſe daies that are not ſo regular as it ſelf is: For,

Suppoſe a Clock ſhould be adjuſted

juſted to the hour at a time when natural daies are ſhorteſt, as about the middle of *March*, this Clock with the ſame pitch of motion, ſhall in *June* or *December* finiſh it's diurnal Revolutions ſooner than the day ſhall do, by reaſon the natural daies are now longer than thoſe of *March*, to which the Clock had been formerly adjuſted; and by conſequence it ſhall now gain upon every day, juſt ſo much time as theſe daies in *December* are longer than thoſe of *March*. So on the contrary, if a Clock be adjuſted to go true with the Sun in the Month of *December*, at which time the natural day is alwayes longeſt, this Clock when natural daies are ſhorter, as in *March* or *September*, ſhall not finiſh it's daily Revolutions ſo ſoon as the day it ſelf ſhall be accompliſhed,

pliſhed, and by conſequence go each day ſo much too ſlow, as thoſe daies of *March* or *September* are more ſhort than them to which the Clock before had been exactly adjuſted.

Since therefore there is no tolerable exactneſs in thus adjuſting Clocks to the Sun it ſelf, becauſe being thus adjuſted at times when daies are either ſhorteſt or longeſt, their gaining or loſing will be the more extream in the contrary parts of the year: for Example; Clocks adjuſted to the Sun in *March* ſhall upon moſt daies in *December* gain almoſt 50 Seconds, which in the Months time ſhall amount to near half an hour; and on the contrary, if adjuſted to go true with the Sun in *December*, it ſhall in *March* loſe the ſame time, and ſo for any

other, according as daies do differ in length.

That Clocks therefore may be reduced to a more exact pitch of motion, that their gain or loſs may never be ſo extream, it will be neceſſary to adjuſt them, ſo as that their motion may be agreeable to that of a middle day, or ſuch a one as is a mean between natural daies that are moſt long, and thoſe others that are moſt ſhort; to which pitch if a Clock be once adjuſted, it's gain or loſs ſhall then be the leſs ſenſible (for gain and loſe it will ſtill) amounting in *December* but to about 15 Minutes in the whole Month, and in *March* to but about 9, which is vaſtly more exact than when it ſhall happen to be adjuſted to the longeſt or ſhorteſt of Natural daies, or to any other

that

that is not equal to a mean or middle day, of which there are but few, which in the Table are expreſt by the Character ⊙ *Sol.*

But to this exact pitch of motion, that may thus correſpond to a mean day (the greateſt exactneſs that a Pendulum is capable of being brought to) there is no way certainly to adjuſt a Clock without the help and aſſiſtance of a Table of Equations, that give the daily differences between a mean day and thoſe which are either longer or ſhorter than the mean day is; which Equations having formerly been computed by the Worthy and Ingenious Mr. *Chriſtian Hugens de Zulechim*, (who is reported to be the firſt that ever applyed the Pendulum to regulate the motion of a Clock) and not long ſince Printed in num-

ber 49. *Philoſ. Tranſ.* I have made bold, in regard of its exactneſs, to tranſcribe in it's more natural form of an Equation, by only expreſſing the Equations themſelves, without adding them together, and ſubſtracting, as Mr. *Hugens* has done for a particular uſe, to ſhew the nature of a Pendulums going, when ſet right the firſt of *February*, and let go the whole year round, without ſetting afterwards.

Now for their ſakes that deſire to know the manner of Compoſing ſuch a Table themſelves, that thereby they may the better underſtand the nature of it; they may Note, that the Equations are to be found out, and a Table compoſed in the manner following: Firſt find out a mean *Right Aſcenſion*, by dividing the 360 degrees of the Equinox

nox into 365 parts, and a quarter, equal to the daies of a year, and the product ſhall be the mean *Right Aſcenſion* deſired, which will be found to be about three Minutes 56 Seconds (according to Sir *Jonas Moors* account of it in his Mathematical Compendium) then by the help of an exact *Ephemerides* (here lyes the difficulty) let the natural *Right Aſcenſions* of the Sun be computed by Calculation, for the Meridian Poſition of the Sun for every day, to Minutes and Seconds; which having done, compare the daily differences of theſe Natural *Right Aſcenſions* with the mean one, by ſtill ſubſtracting the leſſer from the greater, and what remains ſhall be the Equations deſired; ſtill noting down either the exceſs or defect, that is,

whether the natural be more than the mean or leſs: as for example; Suppoſe the *Right Aſcenſion* between the Meridians of the 1ſt. and 2d. of *January* be found to amount to 4 Minutes, 20 Seconds, this compared with the mean *Right Aſcenſions*, 3 Minutes, 56 Seconds, and by ſubſtracting the leſſer from the greater, the remainder will be found to be 24 Seconds, and ſo much the Natural *Right Aſcenſion* does then exceed the mean one; this 24 Seconds is the Equation for that day, it being from noon to noon 24 Seconds longer than a mean day is; and ſhews you, that a Clock when well adjuſted to a mean day, ſhall then gain 24 Seconds, becauſe it finiſhes it's Diurnal Revolutions ſooner by 24 Seconds than the day it ſelf does:

on

on the contrary, when the *Right Aſcenſions* of Natural daies are leſs than the mean ones, as they are about the middle of *March*, by almoſt 20 Seconds, this 20 Seconds being the Equations belonging to ſuch a day, ſhall ſhew you, that upon ſuch a like day a well adjuſted Clock ſhall then loſe 20 Seconds; for the mean day to which it is adjuſted being longer than the natural one by 20 Seconds, the Natural Day ſhall be finiſhed ſooner by 20 Seconds than the Clock at that time ſhall accompliſh it's diurnal or daily Revolutions, and by conſequence it ſhall then loſe 20 Seconds. The Equations thus found for every particular day, and a Table compoſed of them, ſhall reſemble that which is here inſert-

ed, whoſe Uſe we now come to ſhew more particular in ſome Caſes.

For Explanation, take notice, that the firſt Column contains the daies common to every Month, the other 12 Columns that belong to the ſeveral Months themſelves, contain thoſe Seconds of time that all natural daies are either longer or ſhorter than the mean day. Note, that in four parts of the Table are placed this Character ☉, which denotes the times wherein natural daies having before been longer than the mean day, do then begin to be ſhorter; or having before been ſhorter, do then begin to grow more long: Note alſo, that thoſe daies upon which this Character ☉ is affixed, have no Equation, they being equal in their length to the mean

mean day; as for the words inſerted among the Columns, they are at ſight to inform you, that the Equations in thoſe parts of the Table are either more or elſe leſs than the mean day, as the words themſelves do fully expreſs; they alſo note, that where the Equations are more, there Clocks ſhall gain each day ſo much as the Equation belonging to it does then expreſs; but if the Equations are leſs, they then ſhall loſe; and how much this gain or loſs for every particular Months time ſhall amount to, is by continual addition of the Equations belonging to each day ſummed up, and the quantity of time it amounts to, ſet down apart at the bottom of every Column.

Note alſo, that ſince Clocks do either gain or loſe, during the whole

whole number of daies included between thoſe daies on whom this Character ⊙ is affixed, the whole quantity of time either got or loſt does amount to the ſumms that follow, *viz.* Between the 1*ſt* of *February* and the 4*th* of *May*, the time that a well adjuſted Clock ſhall loſe, amounts by continual adding the Equations together, to about 19 Minutes, 29 Seconds; between this 4*th* of *May* and the 15*th* of *July* it ſhall gain about 9 Minutes 43 Seconds; from the 15*th* of *July* to the 23*d* of *October*, it ſhall loſe 22 Minutes 9 Seconds; from the 23*d* of *October* to the laſt of *January*, it ſhall gain 31 Minutes 55 Seconds: All this is to be underſtood of a well adjuſted Clock, ſet right to the Sun at the beginning of each time of either gaining or loſing.

By

By this Table, if you would adjuſt a Clock to a mean time, which is the greateſt exactneſs to which it's poſſible to be brought, do thus: Firſt ſet it true to the Sun, and note the day, then let it's motion be continued without ſetting a new, for about 30 or more daies: Obſerve then the time that it has got or loſt by the Sun, then ſumm up the whole number of Seconds included in the Table, between thoſe two daies of firſt ſetting and laſt Obſervation (allowing 60 Seconds to a Minute) and if the gain or loſs of your Clock be equal to the ſumm of time that it ſhould have gained or loſt by the Table, then is it well adjuſted; but if it have not, then muſt its motion be reduced to a more near agreement, by ſhortning the Pendulum in caſe the Clock have

have gone too ſlow, or letting the Bob down longer in caſe it have gone too faſt: Then ſet it anew, and try it for about 30 daies more, and then comparing its loſs or gain with the ſumm of thoſe Equations contained in the Table, as before you did, let the Bob be again rectified as the nature of it's motion requires; and continue to do thus, till you find its gain or loſs exactly to correſpond with the ſumm of time given by the Equations contained in the Table, for the time that the Clock has gone.

When it is thus well adjuſted to a mean time, it will be ſo exact, as that, being ſet right at any time of the Year, and ſo let go the whole Year about, it ſhall come right with the ſame Dial by which it was ſet the ſame day Twelve-month; but in

n all other parts of the Year it ſhall ſtill differ from the ſame Dial. For Example: If ſet right the firſt of *February*, and ſo continued in Motion the whole Year about, it ſhall continually be too ſlow the whole Year, either more or leſs, till the ſame day on which it was ſet: The reaſon of this is plain enough; for from the firſt of *February* to the 4*th* of *May*, it ſhall continually loſe to the quantity of 19 Minutes, 29 Seconds; then from the 4*th* of *May* to the 15*th* of *July*, it ſhall gain; but this gaining amounting to but about nine Minutes, 43 Seconds, it ſhall ſtill be too ſlow by 9 Minutes, 46 Seconds; becauſe its gaining now ſhall not be ſo much as it loſt before, by 9 Minutes, 43 Seconds: Then again, from the 16*th* of *July* it ſhall loſe afreſh till the 21*ſt* of *October*; which ſecond loſs amounting

mounting to about 22 Minutes, 9 Seconds, this added to the time that it was too slow on the last account, shall amount to 31 Minutes, 55 Seconds, and so much it shall be too slow on the 21*st* of *October*; from whence it shall gain afresh till the last of *January*, to the quantity of 31 Minutes, 55 Seconds; which being equal to what it was before too slow, shall cause it to come right to the same Dial with which it was set twelve Months before, altho' it went too slow the whole Year beside.

Again, let a Clock be set right the 23*d* of *October*, it shall from thence gain time till the last of *January*; and this gain shall amount to 31 Minutes, 55 Seconds; then from the first of *February* to the 4*th* of *May*, it shall lose 19 Minutes,

29 Se-

29 Seconds, which being leſs than the 31 Minutes, 55 Seconds, which before it had got, by about 12 Minutes, 26 Seconds, it ſhall ſtill be too faſt by 12 Minutes 26 Seconds: Then from the 4*th* of *May*, to the 15*th* of *July*, it ſhall gain anew to the quantity of about 9 Minutes 43 Seconds, which added to the time it was too faſt before, ſhall amount to 22 Minutes, 9 Seconds, and ſo much it ſhall be too faſt on the 15*th* of *July*; from which time till the 23*d* of *October*, it ſhall loſe this 22 Minutes, 9 Seconds, and by Conſequence come right to the ſame Dial with which it was ſet twelve Months before.

Thus ſhall one and the ſame Clock, with the ſame pitch of Motion, go alwayes too ſlow if

ſet

ſet at one time of the Year, and always too faſt if ſet at another time, if it be let go the whole Year about.

Moreover, if ſet at ſome other times, and then continued in its Motion for a Year, without ſetting anew, it ſhall both gain and loſe, be ſometimes too faſt, and ſometimes too ſlow: For if a well adjuſted *Pendulum* be ſet right to the Sun the 4*th* of *May*, by the 15*th* of *July* it ſhall be 9 Minutes, 43 Seconds too faſt: From this 15*th* of *July* to the 23*d* of *October*, having loſt 22 Minutes, 9 Seconds; from which ſubſtracting the 9 Minutes, 43 Seconds that it was before too faſt, there remains 12 Minutes, 26 Seconds; and ſo much it ſhall be too ſlow on the 23*d* of *October*; from which day it ſhall begin to gain,

gain, and continue ſo to do till the firſt of *January*, by which time the Clock having got 31 Minutes, 55 Seconds, which amounting to about 19 Minutes, 29 Seconds above what it was too ſlow on the 23*d* of *October*, it ſhall by Conſequence be now 19 Minutes, 29 Seconds too faſt; from whence to the 4*th* of *May*, it ſhall loſe what now it is too faſt, and ſo come right to the ſame Dial with which it was before ſet.

Again, ſet a Clock to the Sun the 15*th* of *July*, and if it be well adjuſted, it ſhall by the 23*d* of *October* be 22 Minutes, 9 Seconds too ſlow; from whence to the laſt of *January*, it being to gain 31 Minutes, 55 Seconds, it ſhall be then 9 Minutes, 46 Seconds too faſt; from which time to the 4*th* of *May*,

it losing 19 Minutes, 29 Seconds, it shall then be 9 Minutes 29 Seconds too slow; which time by the 15*th* of *July* shall again be got, and so the Clock shall come right to the same Dial.

Thus, by this Table, are these great Varieties discoverable in the Motion of the best adjusted *Pendulum*, according to the different times of the Year that it is set in; that the same *Pendulum* set right upon the first of *February*, shall go always too slow till the same day twelvemonth; but if set right the 23*d* of *October*, it shall the whole Year round be still too fast, till the same day on which it was set: The same Clock being also set to the Hour on the 4*th* of *May*, or the 15*th* of *July*, shall on the following Year be

be ſometimes too faſt, and at other times too ſlow. Theſe are all ſtrange and unaccountable things to ſuch as underſtand not the Nature of the Unequality of Time, from whence all theſe Varieties do ſtill ariſe, and are ſcarcely to be demonſtrated to the Underſtanding by any other way, than by this or ſome other Table of the *Æquation of Time.*

Since therefore there is a neceſſity for ſetting Clocks a-new to the Sun, at ſome times, that they may be kept as near as poſſible to the apparent time given by a Dial; I adviſe that this ſetting may be, if poſſible, the firſt day of every Month; ſo may you the better diſcern by the Time ſet down at the bottom of every Column, whether your Clock have gone right to the

mean time, and be as exact in his Motion as 'tis poſſible to bring him to: For if it be exactly adjuſted, it will then either gain or loſe near that time that is ſet down at the bottom of every Month, thoſe Sums being nothing elſe but the Æquations of the whole Month added together into one Summ, as before I directed, when I gave you the Method of adjuſting a *Pendulum* to the true or mean time: But in caſe you cannot ſet it right the firſt day, then muſt you be at a little trouble to add together the *Æquations* your ſelf, at ſuch time as you come to ſet it a-new; but when the Clock is well adjuſted, there needs little of this trouble, being aſſured that it's brought to the neareſt pitch of Motion it's capable of; and that when it is at any time found to differ from

from the Sun, it must be lookt upon as the natural Consequence of the Unequality of Time, and not any Deficiency in the Motion of the Clock.

I speak this of those long and curious *Pendulums* that vibrate within the Compass of 2 or 3 Inches; for the less Compass a *Pendulum* takes, the more steady is it's Motion, not being so subject to rise and fall, as others are, that vibrate in a larger Compass. As for those shorter *Pendulums* of a Foot long, or under, although they may go very steady for the most part, if Frost or foulness hinder not, yet are they not at all intended in this Discourse, their Motion being apt to an Alteration in some Cases; for a short *Pendulum* that goes well when clean,

ſhall go faſter than the mean time when foul, becauſe the *Pendulum* is by the foulneſs hindred from taking its wonted Compaſs: The ſame effect does Froſt produce; for by congealing the Oyl in the Pevets, its freedom of Motion is interrupted, ſo that the Pendulum not fetching it's wonted Compaſs, ſhall go too faſt; but thoſe long and curious Pendulums of 40 Inches, that fetch not above three Inches compaſs, they are ſo exact, that being once adjuſted they ſhall alwayes keep the ſame time, if their motion continue; for if the Pendulum ſhould fetch a ſmaller compaſs, their Motion would ceaſe, and themſelves ſtand ſtill.

When ſuch a Pendulum as this is well adjuſted, you may truſt to it,

it, as to it's correſpondence in Motion with the mean time, and only give your ſelf the trouble ſometimes to ſet it a little forward or backward, according to what the unequality of Time has made it to differ from the ſame Dial with which you did uſe to ſet it; which times of ſetting may be, as I ſaid before, once in a Month; yet if the Table be well noted, you ſhall find, there be ſome times in the year in which a good Clock may go a longer time without any material difference from the time given by a Dial: For Example,

Suppoſe you ſet a Clock right to the Sun the firſt of *January*, this Clock if let go till the firſt of *March*, ſhall then be but two Minutes four Seconds too faſt; for though it gain

in *January* ſix Minutes, no great matter, yet loſing in the next Month about four Minutes, it ſhall at the end of that Month be but two Minutes to faſt; nay, if let go another Month, as to the laſt of *March* is, it ſhall then differ but about ſeven Minutes, which is no great matter. Moreover, if you ſet a Clock the firſt of *May*, it ſhall, if let go till *June*, loſe but two Minutes thirty five Seconds in the whole, though it ſhall at the beginning of *May* be about five Minutes to ſlow, which is no great matter; ſo alſo if it be ſet right the firſt of *June*, it may well go without ſetting till the firſt of *September*; for though it gain five Minutes in *June*, yet loſing eight Minutes in *Auguſt*, it ſhall then be but about three Minutes too ſlow in this three

Months

Months time; but at ſome other times, as from *February* to *May*, if a Clock were let go 'twill be extreamly out, loſing above eighteen Minutes; ſo alſo in *November*, *December* and *January*, in which time it will gain above thirty Minutes.

By the Table you may alſo readily find out, what difference there is between the lengths of any two daies in this manner: Firſt, If the daies are both ſhorter, or both longer than the mean day, then ſubſtract the Equation in the Table belonging to one day from the Equation of the other, and the remainder ſhall ſhew their difference in length. But if the daies be one longer than the mean, and the other ſhorter, then add the two

Equa-

Equations together, and the ſumm ſhall be the time that they differ in length: Thus the tenth of *January* will be found to be thirteen Seconds longer than the tenth of *May*; alſo the fifteenth of *September* will be found to be fifty one Seconds ſhorter than the fifteenth of *December*.

*Note*, That if men be very nice in keeping a Clock true to the Sun, they ſhould then make uſe, if poſſible, of but one time on the Dial that they ſet it with, and that pretty near noon; for few Dials being drawn exactly true, great miſtakes may ariſe, when a Clock is ſet to one hour and then compared with another; and by reaſon of refractions great errours may alſo

ſo ariſe; for the Sun by Refractions being made to appear higher than really ſhe is, there can be no certain account taken of the time till near Noon, where Refractions ceaſe: And when all this care is taken, in regard it is ſo very hard to diſtinguiſh Minutes by the ſhadow of a Dial, you will be much more exact if you do thus: Let two plain and flat plates or boards, about ten Inches ſquare, be joyned ſo cloſe together that a Six-pence may but juſt go between; let them be fixed ſo, that this Cranney between them may reſpect the true *South*; this will give you the time to leſs than half a Minute, by obſerving the firſt moment that the Suns beam is darted through it, and caſt upon ſome dark body that is placed on the North-

North-part to receive the light; ſo that having thus the exact time, when the Sun comes to every Meridian, it will be found a much better way to adjuſt Clocks by ſuch a device as this, than by the trueſt Dial.

One uſe more, and that a Principal one, I ſhall add, that is this: When a Clock is once well adjuſted to the mean or equal day, you may then by this Table keep it right to the time given by the Sun, although you never ſet it right to a Dial, nor ſee the Sun above once a Year; to perform this do thus: ſet your Clock right to the Sun the firſt day of any one Month, and then the Table ſtill giving you the time it ſhould loſe

or

or gain in that whole Months time, 'tis then but ſetting it forward or backward the firſt day of the next Month what it either hath got or loſt in the Month immediately preceding, and it will then be right with the Sun as if it had been ſet by a Dial, and ſo from Month to Month you may (by ſtill ſetting it either forward or backward according to what the Table tells you it will gain or loſe) keep it true to the time given by the Sun, though it ſhould never ſhine ſo as to give you an opportunity to ſet it by a Dial above once in the whole Year; but be ſure your Clock be firſt well adjuſted, or elſe there may be ſome errour: Note, that for this purpoſe it will be very convenient to

Paſte

Paſte the Table it ſelf on a board, and then putting it into a handſom Frame, let it be hung up near the Clock, that you may have ready recourſe to it on all occaſions, eſpecially for this in particular; for without the aſſiſtance of ſuch a Table as this, I know no way in the World to keep a Clock right to the apparent time, in caſe Clouds ſhould intercept the Beams of the Sun for any long time together.

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*FINIS.*

# BOOKS

*Sold by* Joseph Watts, *at the* Half-moon *in St.* Paul's *Church-yard.*

*Josephus*'s Wars of the *Jews. Fol.*

The Tryals of *Thomas Walcot*, *William Hone*, *William* Lord *Russel*, *John Rouse*, and *William Blagg*.

The Confession, Prayers and Meditations of *John Stern*, published by Doctor *Burnet* and Doctor *Horneck*.

The Earl of *Danby*'s Case, and Answer to Sir *Robert Howard*, and his Answer to the Examination of his Case, and Reply.

The Bishops of *England* may, and ought to vote in Cases of Blood.

*Baxter* against *Baxter*.

A serious Expostulation with the *Whiggs* in *Scotland*.

Dr. *Jane*'s Sermon before the Commons, *April* 11. 1679.

Dr. *Perinchief* against Toleration.

*Fowler's*